The epidemiology of noncompressible torso hemorrhage in the wars in Iraq and Afghanistan

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BACKGROUND: Noncompressible torso hemorrhage (NCTH) is the leading cause of potentially survivable trauma in the battlefield and has recently been defined using anatomic and physiologic criteria. The objective of this study was to characterize the frequency and mortality in combat of NCTH using a contemporary definition.

METHODS: Four categories of torso injury, each based on vascular disruption, were identified in US military casualties from the Department of Defense Trauma Registry (2002–2010): (1) thoracic, including lung; (2) solid organ (high-grade spleen, liver, and kidney); (3) named axial vessel; and (4) pelvic fracture with ring disruption. Injuries within these categories were evaluated in the context of physiologic indicator of shock and/or the need for operative hemorrhage control.

RESULTS: Of 15,209 battle injuries sustained during the study period, 12.7% (n = 1,936) had sustained one or more categories of torso injury. Of these, 331 (17.1%) had evidence of shock or the need for urgent hemorrhage control, with a mean (SD) Injury Severity Score (ISS) and mortality rate of 30 (13) and 18.7%, respectively. Pulmonary injuries were most numerous (41.7%), followed by solid-organ (29.3%), vascular (25.7%), and pelvic (15.1%) injuries. Following multivariate analysis, the most mortal injury complexes were identified as major arterial injury (odds ratio, 3.38; 95% confidence interval, 1.17–9.74) and pulmonary injury (odds ratio, 2.23; 95% confidence interval, 1.23–4.98).

CONCLUSION: NCTH can be defined using anatomic parameters combined with physiologic and operative interventions suggestive of hemorrhage. Major arterial and pulmonary injuries contribute most significantly to the mortality burden. (*J Trauma Acute Care Surg*. 2013;74: 830–834. Copyright © 2013 by Lippincott Williams & Wilkins)

LEVEL OF EVIDENCE: Epidemiologic/prognostic study, level III.

KEY WORDS: Wartime injury; noncompressible torso hemorrhage; vascular trauma.

Vascular injury with concomitant hemorrhage is the leading cause of potentially preventable death in both civilian and military trauma patients.[1–9] Studies from the wars in Afghanistan and Iraq have suggested that up to 80% of potentially survivable patients die as a result of exsanguination.[5,6] These studies categorize bleeding broadly in this context as compressible or noncompressible, depending on whether the hemorrhage control measures can be applied soon after the point of injury.

Compressible hemorrhage originates from extremity injury and can be managed by direct application of pressure or a tourniquet. The reemphasis on wartime tourniquet use has increased survival from compressible extremity hemorrhage to greater than 90%.[10–13] In contrast, methods to manage bleeding from sites within the torso, recently referred to as noncompressible torso hemorrhage (NCTH),[9] remain largely limited to the use of conventional operative techniques.[14]

Until recently, despite the intuitive use of the term *noncompressible*, NCTH has lacked a consistent definition with which to characterize the epidemiology of this morbid injury complex. US and UK military surgeons have proposed a definition of NCTH, which includes vascular disruption within the thorax, abdomen, and pelvis, linked to physiologic indices of shock and/or the need for operative hemorrhage control.[14]

The objective of this study was to characterize the prevalence of NCTH in a large population of wartime casualties using this contemporary definition. In that context, an additional objective was to characterize the mortality of this injury pattern within a population of combat wounded and identify sites of vascular disruption within the torso associated with the highest mortality.

PATIENTS AND METHODS

This study was conducted under approval from the US Army Medical Research and Material Command Institutional Review Board. The investigation used the Department of Defence Trauma Registry (DoDTR) to examine the prevalence of NCTH between 2002 and 2010. The DoDTR is housed within the US Army Institute of Surgical Research and is used by the Joint Trauma System as a process improvement tool to benchmark trauma care.[15] Patient data are entered on all US service

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The viewpoints expressed in this article are those of the authors and do not reflect the official position of the US Department of Defense or the UK Defence Medical Service.

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personnel injured while on operations, who are admitted to a medical treatment facility (MTF). In this context, the prevalence of NCTH was examined in troops who survived to receive care at an MTF and not those who died as a result of wounds before reaching medical treatment, also referred to as *killed in action*.[16]

Definition of Noncompressible Torso Vascular Injury and Hemorrhage

Using Abbreviated Injury Scale (AIS) scores, the Joint Theater Trauma System was queried for US service personnel sustaining an injury within one of four categories (Table 1): Category I, main axial torso vessel; Category II, Grade 4 or 5 solid-organ (liver, kidney, or spleen) injury;[17] Category III, massive hemothorax from pulmonary parenchymal injury; and Category IV, open ring pelvic fractures with vascular disruption. Within Category I, the injuries were subdivided into major and minor. Major arterial injury was defined as that to the aorta or named primary branch vessel (e.g., celiac, superior mesenteric, or renal artery), whereas minor injury was defined as that to any tertiary arterial branch (e.g., gastric, gluteal, or gonadal arteries). Venous injuries were similarly defined as major or minor based on the vena cava as the primary axial vessel. Because of their high lethality in the wartime setting, cardiac injuries were not included in the definition of NCTH.[14]

For purposes of the study, two groups were formed from the overall cohort. The noncompressible torso injury (NCTI) group consisted of casualties who were identified as having sustained one or more of the anatomic vascular injury categories by the DoDTR search. In contrast, the NTCH group consisted of patients identified within the overall cohort who also had a physiologic indicator of shock and/or the need for operative hemorrhage control.

Shock was defined as a blood pressure of less than 90 mm Hg on admission to a Role III MTF (equivalent to a US Level I trauma center). The need for operative hemorrhage control was defined as the need for an immediate laparotomy, thoracotomy, or pelvic fixation, identified by DRG International Classification of Diseases—9th Rev. procedure codes. Information collected included demographic, injury and physiologic data, as well as 30-day mortality.

Statistical Analysis

The demographic data, mechanism of injury, admission physiology, injury pattern, and mortality were compared between the NCTI and NCTH groups. Continuous variables were compared using the Student's t test or Mann-Whitney log rank test; categorical variables were compared using the χ^2 test. The injury pattern subdivisions were compared between survivors and nonsurvivors in the NCTH group. Any univariate comparison within the NCTH group where $p \leq 0.20$ was included in a stepwise logistic regression to identify independent predictors of mortality. The strength of the logistic regression model was examined by the area under the receiver operating characteristic curve. Analysis was performed using SPSS 19 software (IBM, New York, NY).

TABLE 1. Definition of NCTH

NCTH is defined as vascular disruption in one or more of the following:
1. Named axial torso vessel
2. Solid organ injury ≥ Grade 4 (liver, kidney, or spleen) plus concomitant shock* or immediate operation.
3. Thoracic cavity (including lung)
4. Pelvic fracture with ring disruption

*Defined as a SBP of less than 90 mm Hg.

TABLE 2. Demographic, Mechanism, Admission Physiology, Injury Pattern, Operative Intervention, and Mortality of Patients With NCTI Versus NCTH

Parameter	NCTI	NCTH	p
n	1,605	331	
Male, n (%)	1,560 (97.2)	328 (99.1)	0.043
Age, mean (SD)	25.8 (6.6)	25.8 (6.4)	0.851
GSW, n (%)	435 (27.1)	79 (23.9)	<0.001
Explosion, n (%)	892 (55.6)	230 (69.5)	
Other, n (%)	278 (17.3)	22 (6.6)	
SBP, mean (SD), mm Hg	134 (24.8)	82.7 (26.1)	<0.001
GCS, mean (SD)	12.0 (4.4)	6.6 (4.9)	<0.001
GCS score < 8, n (%)	319 (19.9)	183 (55.3)	<0.001
ISS, mean (SD)	25.1 (12.2)	30.1 (13.3)	<0.001
Head/neck AIS ≥ 3, n (%)	317 (19.8)	77 (23.3)	0.148
Face AIS ≥ 3, n (%)	76 (4.7)	11 (3.3)	0.259
Chest AIS ≥ 3, n (%)	1,115 (69.5)	223 (67.4)	0.452
Abdomen AIS ≥ 3, n (%)	609 (37.9)	183 (55.3)	<0.001
Extremity AIS ≥ 3, n (%)	718 (44.7)	206 (62.2)	<0.001
External AIS ≥ 3, n (%)	52 (3.2)	17 (5.1)	0.090
Torso vessel injury, n (%)	257 (16.0)	85 (25.7)	<0.001
Chest injury, n (%)	853 (53.1)	138 (41.7)	<0.001
Solid organ injury, n (%)	342 (21.3)	97 (29.3)	<0.001
Pelvic injury, n (%)	197 (12.3)	50 (15.1)	0.010
Laparotomy	336 (20.9)	215 (65.0)	<0.001
Thoracotomy	41 (2.6)	67 (20.2)	<0.001
Pelvic External-Fixation	64 (4.0)	37 (11.1)	0.057
Tube Thoracostomy	643 (40.1)	185 (55.9)	<0.001
Mortality	142 (8.8)	62 (18.7)	<0.001

RESULTS

Of 15,209 battle injuries reported within the Joint Theater Trauma System during the study period, 12.7% (n = 1,936) sustained an injury within one or more of the categories defined in Table 1. Most patients (97.6%; n = 1,920) in the overall cohort were male and the mean (SD) age was 25.8 (6.6) years. The mean (SD) Injury Severity Score (ISS) of the overall cohort was 26.0 (12.6), with 57.0% (n = 1,122) of patients injured by blast, 26.1% (n = 514) by gunshot, and the remainder by blunt mechanisms (e.g., helicopter or vehicle crash). Of patients in the overall cohort, 17.1% (n = 331) met physiologic and/or operative criteria indicating active hemorrhage (Table 1) and formed the NCTH group. The remaining 1,605 patients formed the NCTI group.

When comparing the NCTI and NCTH groups (Table 2), there were more males in the NCTH group ($p = 0.043$), who also had sustained significantly more blast-related injuries ($p < 0.001$). The NCTH group also had a lower mean admission systolic blood pressure (SBP) (a selection criteria), a lower

Glasgow Coma Scale (GCS) score, and higher mean ISS ($p < 0.001$). When comparing severe injury per body region (defined as an AIS ≥ 3), the NCTH group had a greater proportion of abdominal and extremity injury compared with the NCTI group ($p < 0.001$).

Among the NCTI group, the most common injury involved the pulmonary parenchyma (53.1%) followed by a solid-organ injury (21.3%), named torso vessel (16.0%), and finally complex pelvic fracture (12.3%) (Fig. 1). The most commonly injured solid organ was the spleen (10.5%), followed by the liver (6.7%) and the kidney (3.9%).

A similar distribution of injuries was observed within the NCTH group, although the relative proportions were greater, with the exception of pulmonary injury (41.7%). Solid-organ injury occurred in 29.3%, named vessel injury occurred in 25.7%, and pelvic injury occurred in 15.1%. Again, the spleen was the most commonly injured solid organ (12.4%), followed by the liver (10.0%) and the kidney (15.1%) (Fig. 1).

In operative intervention, consistent with an increased injury severity, a greater number of interventions were performed on the NCTH group (Table 2). More than half of the NCTH group required tube thoracostomy or laparotomy, compared with less than half in the NCTI group. There was a 10-fold increase in the need for thoracotomy in the NCTH group compared with the NCTI group. The greater injury burden is also reflected in the mortality, with the NCTH group sustaining more than twice the number of deaths than the NCTI group (18.7% vs. 8.8%; $p < 0.001$).

Table 3 presents a comparison of the injury pattern of survivors compared with nonsurvivors within the NCTH group. There are a greater proportion of major arterial, major venous, and pulmonary parenchymal injuries in nonsurvivors. In contrast, the survivor group had a higher percentage of splenic injuries, with no difference between the other solid organs or pelvic injuries.

When univariate parameters had a $p \leq 0.20$, they were entered into a multivariate logistic regression to determine factors associated with mortality (Table 4). The following parameters were entered into the model: admission SBP, admission GCS score, and major arterial, major venous, pulmonary, and splenic injuries. SBP and GCS score were significant physiologic parameters ($p < 0.001$). For injury pattern, major arterial and pulmonary injuries were significantly associated with mortality, whereas survival from NCTH was significantly associated with splenic injury. The area under the receiver operating characteristic curve was 0.774.

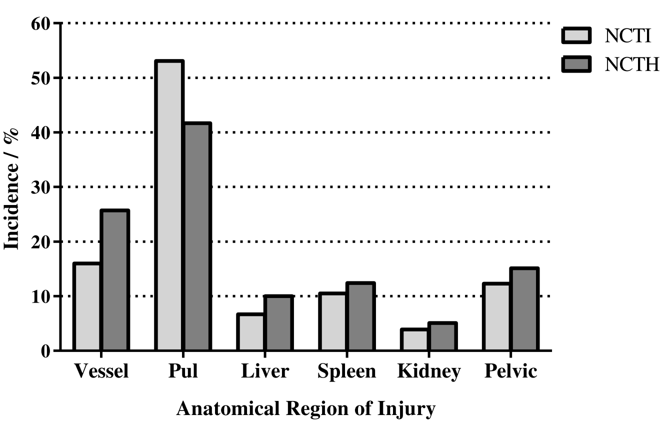

Figure 1. The incidence of specific injury complexes for patients with noncompressible injury and hemorrhage as a percentage.

TABLE 3. Comparison of Injury Patterns in Patients With NCTH, Survivors Versus Nonsurvivors

Injury Type	Survivor, n (%)	Nonsurvivors, n (%)	*p*
n	269	62	
Major arterial	25 (9.3)	16 (25.8)	<0.001
Minor arterial	13 (4.8)	4 (6.5)	0.603
Major venous	23 (8.6)	11 (17.1)	0.032
Minor venous	8 (3.0)	2 (3.2)	0.917
Pulmonary injury	103 (38.3)	35 (56.5)	0.026
Liver	23 (8.6)	11 (17.7)	0.349
Spleen	38 (14.1)	3 (4.8)	0.032
Kidney	13 (4.8)	4 (6.5)	0.817
Pelvic fracture	42 (15.6)	8 (12.9)	0.591

DISCUSSION

This study uses a new definition of NCTH based on specific anatomic, physiologic, and procedural indices reflective of hemorrhage. Findings from this study demonstrate that 12.7% of wounded in combat sustain an anatomic injury pattern that is at risk for NCTH, and of these, 17.1% had evidence of ongoing hemorrhage. Casualties with this injury pattern and indicators of noncompressible hemorrhage have twice the mortality compared with those with the at-risk injury pattern alone. Major arterial and pulmonary are the injury patterns associated with the highest mortality, while injury to the spleen is associated with survival.

This current study confirms and extends the work of Holcomb et al.[9] who published one of the first studies to recognize the importance of uncontrolled truncal hemorrhage. The autopsy findings of 82 special operations forces personnel killed early in the wars in Afghanistan and Iraq, between 2001 and 2004, were reviewed by a panel of experts and judged as nonsurvivable (e.g., lethal head or cardiac wounds) or potentially salvageable. While there were subjective aspects to the methodology of this study, it was one of the first studies to specifically use the term *noncompressible truncal hemorrhage*, although it was not specifically defined. Truncal hemorrhage was found to be the cause of death in 50% of patients judged to have sustained potentially survivable injuries.

TABLE 4. Multivariate Regression Analysis of Significant Univariate Parameters for Mortality in Patients With NCTH

Parameter	Odds Ratio	95% Confidence Interval	*p*
Major arterial injury	3.38	(1.17–9.74)	0.024
Pulmonary injury	2.23	(1.23–4.98)	0.050
Splenic injury	0.82	(0.67–0.98)	0.047
SBP	0.97	(0.96–0.99)	<0.001
GC score	0.92	(0.83–1.00)	<0.001

Kelly at al.[5] used a similar methodology to analyze 997 US military deaths that occurred within two periods: 2003 to 2004 and 2006. Hemorrhage was the leading cause of death in those with otherwise survivable injuries and accounted for 87% and 83% of deaths during these respective periods. Airway problems, head injury, and sepsis constituted the remaining causes of death. Interestingly, these figures remained unchanged when Eastridge et al.[6,8] expanded this analysis to US military personnel who died of wounds in 2001 to 2009 and all deaths in 2001 to 2011. While lethal head injury was the dominant pattern of trauma in the nonsurvivable cases, hemorrhage again accounted for 80% to 90% of potentially survivable deaths, with truncal hemorrhage accounting for 48% to 67% deaths in these analyses.

The publication of these studies provided an important characterization of battlefield injury and illustrated the high and early lethality of NCTH in those who could have otherwise survived their injuries. These studies are largely responsible for the institution of tourniquets and other tactical combat casualty care maneuvers, many of which have been shown to improve survivability following wartime injury.[12,13] The current study extends these findings to enable a characterization of the contribution of specific injury patterns within the umbrella of NCTH.

The finding that pulmonary injury followed by major vascular injury contributes greatest to the mortality burden is supported by several clinical studies examining the incidence of hemorrhage in particular organ systems.[7,18] Propper et al.[18] examined wartime thoracic injury from 2002 to 2009. The authors found that thoracic injury of any type occurred in 5% of wartime casualties, with a mean ISS of 15 and crude mortality of 12%. The most common thoracic injury pattern in the study of Propper et al. was pulmonary contusion (32%), followed by hemopneumothorax (19%).

In a separate study, White et al.[7] reported the incidence of vascular injury in US troops between 2002 and 2009. The authors of this study observed a specific vascular injury rate of 12% (1,570 of 13,075), which was five times higher than that described in previous in wartime reports. Large vessel injury accounted for 12% of the torso vascular injuries in the study of White et al., with iliac, aortic, and subclavian vessels being the most commonly injured. These findings were later extended to a comparison of military patients with a propensity-matched cohort from the National Trauma Data Bank.[19] For noncompressible arterial injury, the military had a significantly lower mortality compared with a civilian population (10.8% vs. 36.4%; $p = 0.008$).

The low mortality associated with splenic injury in this study is not surprising in comparison with other injury patterns. While the control of splenic hemorrhage can be challenging, definitive hemorrhage control via splenectomy is relatively more straightforward in contrast to the complex management of torso vascular or pulmonary hemorrhage. Recently, Zonies and Eastridge[20] reported 10 years of wartime splenic trauma management with a series of 393 patients with only 11 of 36 deaths caused by uncontrolled splenic hemorrhage (2.8%).

This study has a number of limitations, inherent to any retrospective study from a combat zone. The US DoDTR is designed as a performance improvement tool and not as a clinical record; thus, it cannot be viewed as such. However, injury pattern data are collected prospectively and frequently updated, although this does not include cause of death. An additional consideration is that data collection commences upon admission to a medical treatment facility, and thus, patient initially treated at lower echelons of care may not have been included.

CONCLUSION

Ultimately, NCTH has been identified as a significant burden of mortality in patients sustaining battlefield injury, with highest mortality found in axial vessel and pulmonary injury. Novel methods of hemorrhage control and resuscitation, which can be initiated in the prehospital setting, are required to reduce the high mortality of this injury pattern.

AUTHORSHIP

A.S. and T.E.R. conceived the study. A.S., R.A.I., and T.E.R. acquired the data. J.J.M., D.J.S., J.D.R., and T.E.R. interpreted the data and wrote the manuscript. T.E.R. led the project.

DISCLOSURE

The authors declare no conflicts of interest.

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